Course Description
Design and simulation of electronic circuits modeling brain cells, including neurons and glial cells; ion channels, synapses, dendritic computations, plasticity, inhibition circuits included; low-power design; simulation laboratory

Learning Objectives
The student will learn the structure and operation of existing circuits that model brain cells and will be able to design extensions of at least a third of these circuits to extend capabilities or to meet design goals such as fanout or power.

Prerequisite(s): EE 477L or EE 479 or EE 348 or equivalent, graduate standing in EE or BME or instructor permission

Course Notes
Letter grade; extensive use of web pages, Blackboard or DEN Blackboard, google drive and Piazza discussion board

Technological Proficiency and Hardware/Software Required
Unix/Cadence experience; account on Viterbi server required
Required Readings and Supplementary Materials
Readings will primarily be taken from dissertations, conference and journal publications, particularly IEEE. Some excerpts from classic textbooks (e.g. Mead’s groundbreaking 1986 text) will be included.

Description and Assessment of Assignments
Students will read assignments from the literature and come to class prepared to present a summary of each assignment. As the semester progresses, each student will be required to present a detailed tutorial on a selected reading. Students will be assigned simulation laboratory assignments on selected circuits taken from the literature. At the end of the semester students will assemble a complex neuron or neural network as a final project.

Grading Breakdown

- Participation 15% (includes presentation/submission of summaries of readings)
- Tutorial presentations 20%
- Laboratory Assignments 40%
- Final Project 25%

Assignment Submission Policy
Students will submit labs online using Blackboard or DEN Blackboard

Additional Policies
Late assignments will be deducted as follows: 5% for the first day late
10% for each subsequent day late up to a total of 50% deducted

Late point deductions will be waived for illness or at the instructor’s discretion
## Course Schedule: A Weekly Breakdown

<table>
<thead>
<tr>
<th>Week 1 Dates</th>
<th>Topics/Daily Activities</th>
<th>Readings and Homework*</th>
<th>Deliverable/ Due Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Introduction to classic neuromorphic circuits</td>
<td>Classic Mead text¹</td>
<td>Prepare summary for class presentation</td>
</tr>
<tr>
<td>Week 2 Dates</td>
<td>(Leaky) Integrate and fire neural circuits</td>
<td>Izhikevich paper²,³,⁴</td>
<td>Prepare summary for class presentation - Lab 1 due</td>
</tr>
<tr>
<td>Week 3 Dates</td>
<td>Ion channel models and circuits: Hodgkin-Huxley model/FitzHugh-Nagumo model/ thermodynamic model and circuits</td>
<td>FitzHugh reference and Hodgkin paper⁵, Hynna thesis (selected readings)⁶, Linares-Barranco paper,⁷ Malmivuo text⁸</td>
<td>Prepare summaries for class presentation</td>
</tr>
<tr>
<td>Week 4 Dates</td>
<td>Synapse circuits - excitatory, Hyperpolarizing inhibitory, shunting inhibitory</td>
<td>Indiveri⁹ Boahen¹⁰, BioRC¹¹, Joshi¹²</td>
<td>Prepare summaries for class presentation Lab 2 due</td>
</tr>
<tr>
<td>Week 5 Dates</td>
<td>Dendritic Computations, Cable Theory and Compartmental Models, Hsu model</td>
<td>Bartlett Mel et al.¹³, Hsu thesis selected readings¹⁴, Farquhar and Hasler¹⁵</td>
<td>Prepare summaries for class presentation</td>
</tr>
<tr>
<td>Week 6 Dates</td>
<td>Spike timing dependent plasticity</td>
<td>Markram¹⁶, Joshi¹²</td>
<td>Prepare summaries for class presentation Lab 3 due</td>
</tr>
<tr>
<td>Week 7 Dates</td>
<td>Structural plasticity</td>
<td>Celikel¹⁷, Joshi¹⁸</td>
<td>Prepare summaries for class presentation</td>
</tr>
<tr>
<td>Week 8 Dates</td>
<td>Connectivity - Address event representation, Rent’s rule</td>
<td>Mahowald thesis¹⁹</td>
<td>Prepare summary for class presentation Lab 4 due</td>
</tr>
<tr>
<td>Week 9 Dates</td>
<td>Glial Cells</td>
<td>Fields²⁰, Joshi²¹, Irrizarry-Valle²²</td>
<td>Prepare summaries for class presentation</td>
</tr>
<tr>
<td>Week 10 Dates</td>
<td>Large scale systems</td>
<td>Markram Blue Brain²³, Spinnaker²⁴, Cattell paper²⁵</td>
<td>Prepare summaries for class presentation</td>
</tr>
<tr>
<td>Week 11 Dates</td>
<td>Student Presentations and Discussion</td>
<td>After presentation students prepare summaries</td>
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</tr>
<tr>
<td>Week 12 Dates</td>
<td>Student Presentations and Discussion</td>
<td>After presentation students prepare summaries</td>
<td></td>
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<tr>
<td>Week 13 Dates</td>
<td>Student Presentations and Discussion</td>
<td>After presentation students prepare summaries</td>
<td></td>
</tr>
<tr>
<td>Week 14 Dates</td>
<td>Student Presentations and Discussion</td>
<td>After presentation students prepare summaries</td>
<td></td>
</tr>
<tr>
<td>Week 15 Dates</td>
<td>Student Presentations and Discussion</td>
<td>After presentation students prepare summaries</td>
<td></td>
</tr>
<tr>
<td><strong>FINAL Date</strong></td>
<td><strong>Final project will be due date of the scheduled final exam</strong></td>
<td><strong>Date:</strong> For the date and time of the final for this class, consult the USC Schedule of Classes at <a href="http://www.usc.edu/soc">www.usc.edu/soc</a>.</td>
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</tr>
</tbody>
</table>
The readings below are representative of the readings assigned in the course. Substitutions may be made as newer research emerges or tutorials become available.


11. **A Carbon Nanotube Cortical Neuron with Spike-Timing-Dependent Plasticity**  
Jonathan Joshi, Alice C. Parker, and Chih-Chieh Hsu, *Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, Sept. 2-6, 2009


13. **Location-dependent excitatory synaptic interactions in pyramidal neuron dendrites.** Behabadi BF, Polsky A, Jadi M, Schiller J, **Mel BW**.  

14. **DENDRITIC COMPUTATION AND PLASTICITY IN NEUROMORPHIC CIRCUITS**, Chih-Chieh Hsu, University of Southern California, 2014.


19. **An analog VLSI system for stereoscopic vision** - Mahowald - 1994


Lab Assignments:
1. Ion channel circuit simulation
2. Leaky Integrate and Fire neuron simulation
3. Detailed synapse simulation
4. Final Project

Statement on Academic Conduct and Support Systems

Academic Conduct
Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words - is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in Scampus in Section 11, Behavior Violating University Standardshttps://scampus.usc.edu/1100-behavior-violating-university-standards-and-appropriate-sanctions/. Other forms of academic dishonesty are equally unacceptable. See additional information in Scampus and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct/.

Discrimination, sexual assault, and harassment are not tolerated by the university. You are encouraged to report any incidents to the Office of Equity and Diversity http://equity.usc.edu/ or to the Department of Public Safety http://capsnet.usc.edu/department/department-public-safety/online-forms/contact-us. This is important for the safety whole USC community. Another member of the university community – such as a friend, classmate, advisor, or faculty member – can help initiate the report, or can initiate the report on behalf of another person. The Center for Women and Men http://www.usc.edu/student-affairs/cwm/ provides 24/7 confidential support, and the sexual assault resource center webpage sarceusc.edu describes reporting options and other resources.

Support Systems
A number of USC’s schools provide support for students who need help with scholarly writing. Check with your advisor or program staff to find out more. Students whose primary language is not English should check with the American Language Institute http://dornsife.usc.edu/ali, which sponsors courses and workshops specifically for international graduate students. The Office of Disability Services and Programs http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html provides certification for students with disabilities and helps arrange the relevant accommodations. If an officially declared emergency makes travel to campus infeasible, USC Emergency Information http://emergency.usc.edu/ will provide safety and other updates, including ways in which instruction will be continued by means of blackboard, teleconferencing, and other technology.

Emergency Preparedness/Course Continuity in a Crisis
In case of a declared emergency if travel to campus is not feasible, USC executive leadership will announce an electronic way for instructors to teach students in their residence halls or homes using a combination of Blackboard, teleconferencing, and other technologies.